PCAS 18 (2015/2016)

Supervised Project Report

(ANTA604)

Comparison of high resolution ENVISAT global monitoring sea ice data to low resolution SSM/I sea ice concentrations in the Ross Sea

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Word count: 3345

Abstract/executive summary (ca. 200 words):

Sea ice extent around Antarctica has increased slightly over the past few decades. Sea ice is an important component of the global climate system, it releases heat when it forms and takes in heat when it melts which affects ocean circulation, and it also reflects solar radiation reducing warming on the ocean surface. This project outlines an initial use of ENVISATs Antarctic data on sea ice, it looks at Synthetic Aperture Radar (SAR) images of the Ross Sea in late May 2011. The high resolution images portray features in details and this report interprets the details within the image to gain information on sea ice during this period. Low resolution SSM/I sea ice concentration images were compared to the high resolution images which enabled a deeper insight into sea ice within the Ross Sea.

Introduction

Sea ice around Antarctica forms seasonally in early autumn and winter with most ice disappearing over spring and summer, while some sea ice remains year round. The result of this is a significant increase in sea ice extent during the winter months (Kimura & Wakatsuchi 2011), which is approximately 50% larger than the Antarctic continent (Lubin & Massom 2006). The maximum extent of the ice occurs in September and October and is at its least in February (Lubin & Massom 2006). Sea ice plays an important role in the global climate system, latent heat is released into the ocean and atmosphere when sea ice forms, and salt in the ocean is rejected by the ice which therefore increases the salinity of the ocean underneath (Kimura & Wakatsuchi 2011). This rejection creates Dense Shelf Water which leads to the production of and is part of Antarctic Bottom Water (Comiso et al. 2011). When sea ice melts it takes in latent heat from the surrounding air and ocean, providing fresh water to the ocean as it melts (Kimura & Wakatsuchi 2011). The snow covering sea ice reflects incoming solar radiation which reduces the impact of warming on the surface of the ocean (Lubin & Massom 2006).

The extent of Antarctic sea ice has increased marginally over the past thirty years, an increase of sea ice extent in the Ross Sea of 1.1% per decade from 1979 to 1998 has been observed (Lubin & Massom 2006), whereas the Arctic has seen significant sea ice loss in this time (Parkinson 2014). The Bellingshausen Sea and the Pacific Ocean area off Antarctica have also shown an increase in sea ice extent (Heil, Fowler & Lake 2006). The Bellingshausen and Amundsen Seas have exhibited significant decreases in sea ice extent, they are positioned to the west side of the Antarctic Peninsula where significant warming has occurred, the Indian Ocean area has exhibited a small decrease in sea ice extent (Heil, Fowler & Lake 2006). However, sea ice extent overall around Antarctica has increased, the exact reasons behind this increase is not known (Parkinson 2014). The maximum sea ice extent around Antarctica was recorded in September 2012 (Parkinson 2014). The Ross Sea has been found to exhibit an increase in sea ice extent while experiencing a decrease in sea surface temperature, this is a unique occurrence in the Southern Ocean. This is considered possibly to be a result of either the El Niño–Southern Oscillation (ENSO), and the Southern Annular Mode (SAM) either independently or both (Comiso et al. 2011).

Satellites are useful in acquiring large-scale information on polar regions, such as information on sea ice and ice sheets. In the early days of satellites, the focus was on low and mid-latitudes and were therefore not useful to researchers aiming to study the poles from space (Lubin & Massom 2007). Satellites have been used to measure the extent of sea ice since the 1970s (Lubin & Massom 2006) and many satellite programs have been completely focused on polar regions (Lubin & Massom 2007). The sensors on satellites wavelengths are determined by the manufacturer based on the physical geographical elements being studied. Polar regions often experience cloud cover, microwave imagers are able to penetrate cloud unlike visible and infrared imagers, therefore they are useful in providing information on ice sheets and sea ice (Lubin & Massom 2007). The interaction of satellites with sea ice and snow layers depends on many factors of surface properties and instrument parameters such as wavelength and polarisation (Lubin & Massom 2006).

There are two main types of microwave radars used on satellites, images in this report were acquired using both types of radars. Passive microwave radiometers measure natural thermal emissions reflected or emitted by the earth's atmospheric system. Generally, passive sensors operate by choosing the wavelength required by the radiation being sent through a device, the radiation at this wavelength is then recorded by a detector by recording an electrical signal equal to the radiations intensity (Lubin & Massom 2007). They supply consistent and extensive information on the large-scale of global sea ice cover characteristics, being able to measure through clouds and in darkness. However, they exhibit poor resolution, being up to tens of kilometres but are useful in gaining an overview of sea ice distribution (Lubin & Massom 2006). Passive microwave radiometers provide images of sea ice type and concentration (Lubin & Massom 2007). These radars provide the most information on global ice concentration and extent (Lubin & Massom 2006).

Active Microwave Radars emit microwave signals from a transmitter, the amount of energy reflected or scattered back from the target surface to the sensor is recorded. They are also able to gain information on ice and snow uninterrupted by cloud and darkness. These radars are able to go through the snow and ice surface and gain information on internal properties (Lubin & Massom 2006). Synthetic Aperture Radars (SARs) are active microwave radars, they provide information on processes on horizontal scales from tens of meters to hundreds of kilometres in high resolution (Partington & Hanna 1994). They are useful for researchers to research a certain area and identify features such as polynyas and pressure ridges. However, data volume is high and it is a complex task to process and analyse the data. SAR uses a technique to increase the satellites spatial resolution, it modifies the along-track movement of the satellite to establish a large aperture (antenna) in space. To do this both the amplitude and phase of the signal being returned is measured. The swath widths of SARs are determined as a result of the radar pulse, therefore higher resolutions have smaller widths (Lubin & Massom 2006). SAR is able to distinguish open water and various ice types by using the amplitude of the return signal as determined by the surfaces volume or surface scattering properties (Lubin & Massom 2007).

This report is an initial assessment of the high resolution Antarctic sea ice data by ENVISAT which visually investigates images generated by this satellite. The high resolution images are compared to lower resolution SSM/I sea ice concentration images to outline features and determine similarities in the images and events occurring on the 27th May 2011 and the days leading up to this date.

Methods

This project uses high resolution images of Antarctic sea ice by ENVISAT and low resolution sea ice concentration SSM/I images. The Advanced Synthetic Aperture Radar (ASAR) Global Monitoring (GM) Mosaic Service for Antarctica was created using the European Space Agencies (ESAs) ENIVSAT polar-orbiting satellite. The mosaic is constituted of numerous GMM stripes overlayed with one another, the images of the continent are captured in 3 to 4 days with 14 images a day in 8000km long and 400 km wide swaths at 400 metre resolution.

Data acquired for this mosaic was collected from 2002 to 2012 when recording ended suddenly in April (European Space Agency 2016). The Special Sensor Microwave/Imager (SSM/I) data is of lower resolution at 25 km acquired through CERSAT from the German sea ice website and represents sea ice concentrations on the same day in the Ross Sea.

The date for this project was selected using the ENVISAT images. Data from each year from 2002 to 2011 was observed and 2011 exhibited the greatest range in data, particularly for the winter period. Many other years lack data in whole months and at months at a time, while also only exhibiting data parts of months. Therefore, with the extent of data available the year 2011 was chosen. The data available for this year was investigated visually and dates with unique or interesting elements such as sea ice movement were selected by observing the Antarctic mosaics. The 27th of May was then selected to narrow down the data range and to focus on one date to ensure a more in-depth comparison of this new high resolution data with lower resolution satellite data, using a swath from the mosaic. The area of study was limited to the Ross Sea in order to narrow data the data and observe one area in depth.

A swath of the Ross Sea at from the 27th May at 15:15 from ENVISAT was used as the main tool of comparison for this project, it was overlayed with a zoomed in coloured SSM/I image of sea ice concentration. Images from the Ross Sea high resolution mosaics were also compared with the low resolution sea ice concentration images and placed side by side to gain a perspective of sea ice activity in the Ross Sea in the days before the 27th of May and to compare the images and what is able to be seen.

Results

The high resolution image has enabled the perception of different features of the sea ice (Figure 1). A dark area is depicted next to the Ross Ice Shelf, while further out from there bright white is able to be seen in waves which spreads out to the right of the image. White lines are visible in many parts of the figure amongst dark sections of the ice. There are numerous dark and grey patches scattered throughout the image.

The low resolution image outlines sea ice concentrations in the area, many areas close to the coast exhibited lower sea ice concentration than surrounding ice. While, further away from the coast appears large areas of yellow which are higher in concentration then red areas both near the coast, further from shore and a large section to the right of the image which represent 100% sea ice concentration.

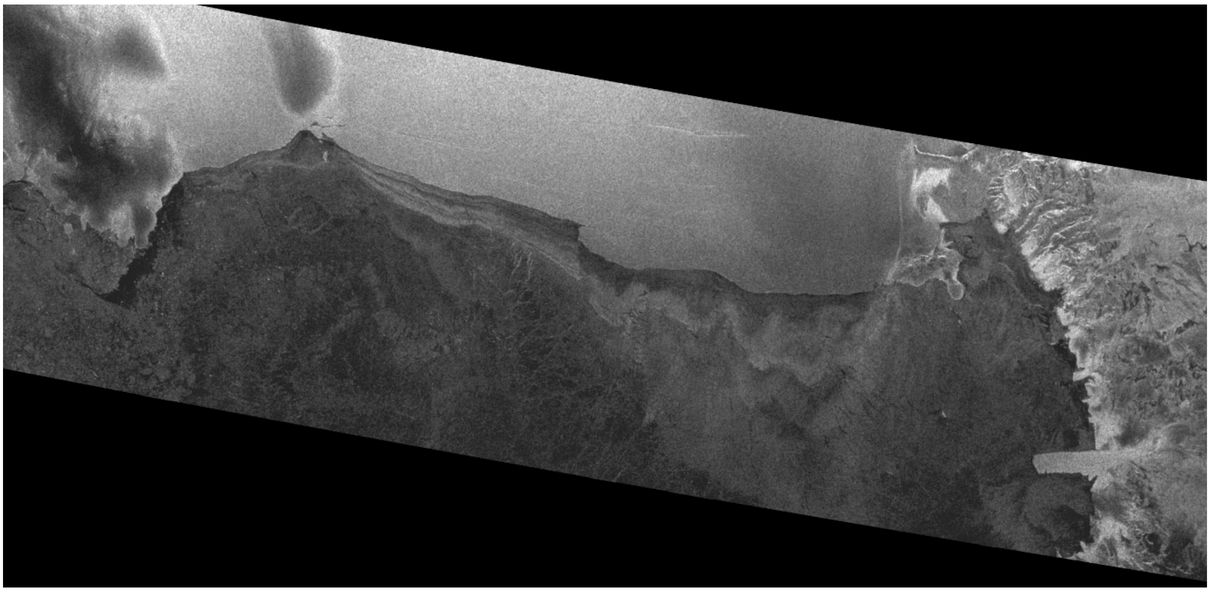

Figure 1. High resolution ENVISAT image of Ross Sea on 27 May 2011.

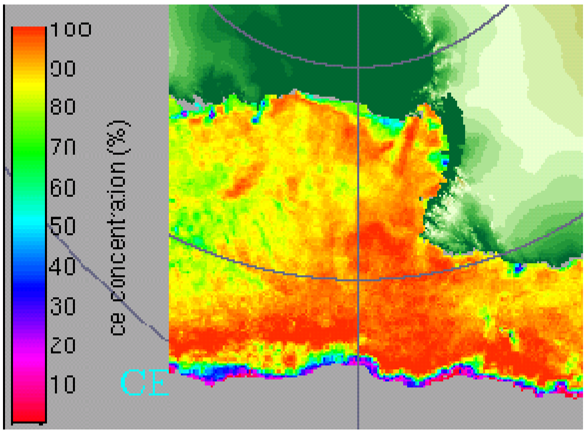

Figure 2. SSM/I sea ice concentration image of Ross Sea on 27 May 2011.

The high and low resolution images overlayed with one another reveal similarities in structure of sea ice on the 27th May 2011 (Figure 3). Variations in the sea ice is reflected in the same areas in both images. There are numerous blue patches around the coast reflecting a smaller concentration of sea ice. Higher concentrations of sea ice in red and yellow are evident in areas close to the coast but also further from the coast. A dark area next to the right side of the Ross Ice Shelf on the ENVISAT image reflects a reduction in sea ice concentration as noted on the low resolution image. A dark blue dot is evident next to a glacier tongue to the right of the image and another to the left, indicating low sea ice concentrations.

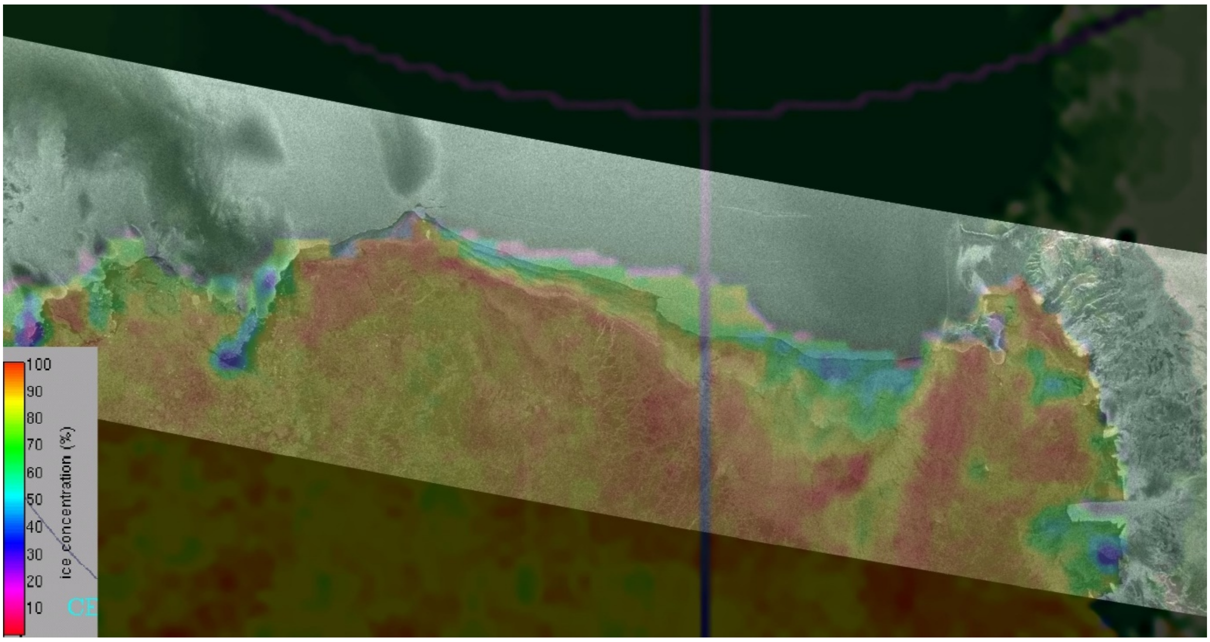

Figure 3. Overlayed image of 400m resolution ENVISAT with SSM/I low resolution image in the Ross Sea 27 May 2011.

The comparison of the ENVISAT and SSM/I image sequence of the Ross Sea (Figure 4) reveal changes in sea ice concentration through the period of the seven days. From the 20th to the 27th a significant amount of red has disappeared from the sea ice concentrations settling to yellow, a lower sea ice concentration. This corresponds to movement of white lines outward to sea on the high resolution images. The dark patch next to the Ross Ice Shelf was evident around the 20th of May and reflects low sea ice concentrations, which persisted until the 27th. The two other areas to the left and right of the image reveal low sea ice concentrations were persistent during this time frame. There were no ENVISAT images for the 23 and 24 of May, therefore these dates were not included in Figure 4.

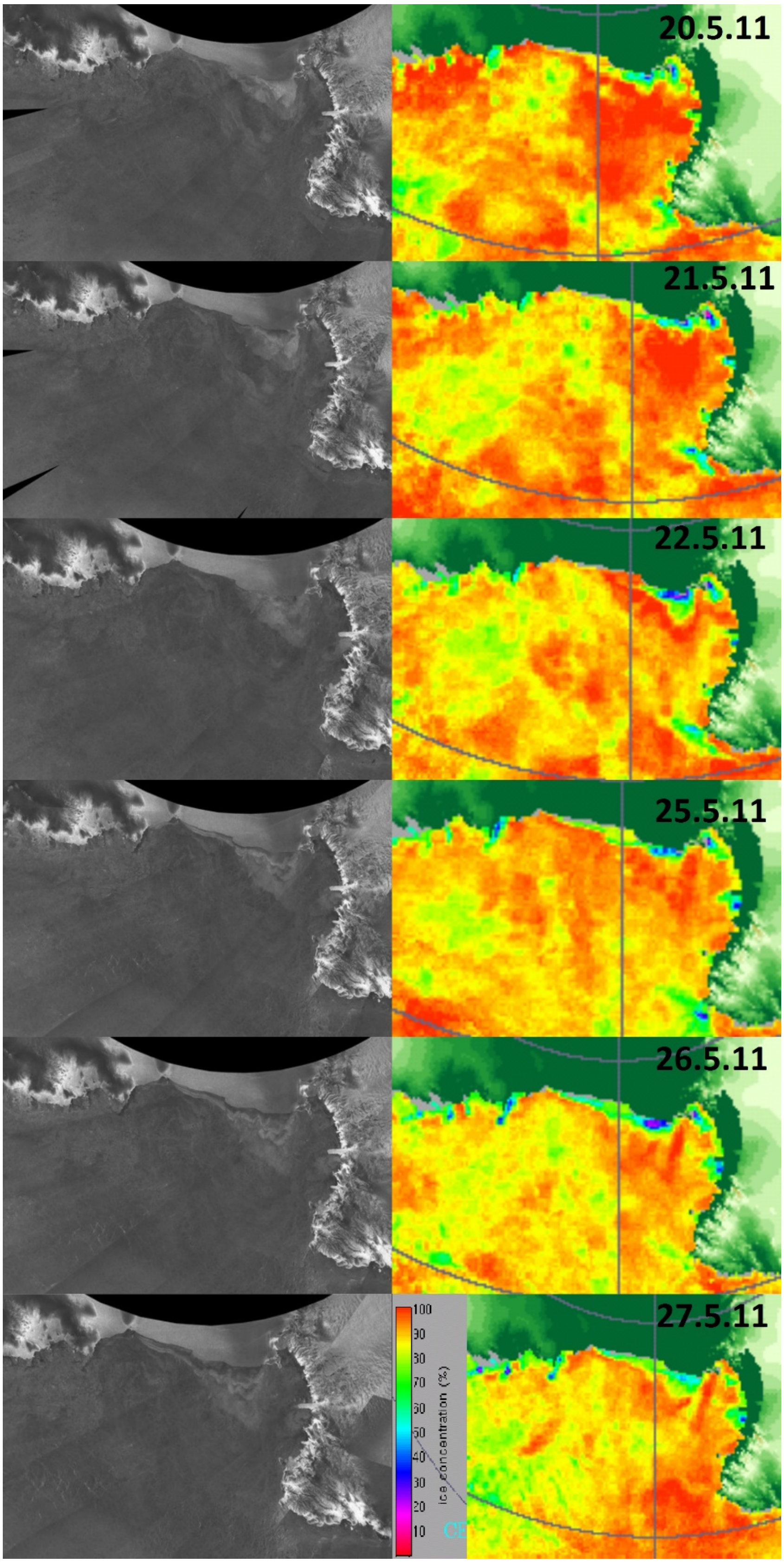

Figure 4. Comparison of ENVISAT mosaic image and SSM/I sea ice concentrations image of the Ross Sea on 20 to 22 and 25 to 27 of May 2011.

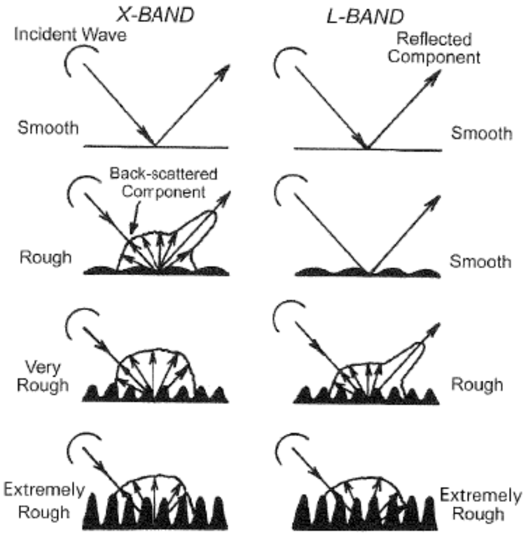

Figure 5. Backscatter properties are dependent on the roughness of the target surface (Lubin & Massom 2006).

Discussion

Lubin & Massom (2007) outline that with SARs the signal received back to the satellites sensor is based on the volume or surface scattering characteristics of the target area and this is what can distinguish between the different ice types and ocean (Figure 5). Lubin & Massom (2006) describes the scattering properties of the target area results in the intensity of the signal received back by the sensor, this is also known as backscatter. The parts of the signal that are not reflected back to the sensor may be reflected elsewhere than towards the radar or be absorbed by the target area. The roughness of a surface to microwave energy is determined by the wavelength and incidence angle of the radar beam and the height of the surface. Generally, rough surfaces reflect much of the incident radiation back to where it came from and creating high backscatter, this creates a bright area on the images. Smooth surfaces reflect a large portion of radiation away from the satellite sensor, creating low backscatter and the area appearing dark in an image. Under calm conditions open ocean that does not contain ice appears dark in the SAR image, if the ocean is under the influence of wind it will appear rougher and therefore more backscatter is present and the area appears lighter (Lubin & Massom 2006).

The ENIVSAT images are from a SAR and are of high resolution as able to be observed in Figure 1. The high resolution image (Figure 1) reveals white and black tones, the edge along the Ross Ice Shelf appears largely grey and black with white along the left side. The dark or grey area suggests calm open water as a result of strong backscatter or smooth new ice with a medium backscatter (Lubin & Massom 2006). Below the grey line next the ice shelf resides white waves of lines, Lubin & Massom (2006) describe deformed thick, deformed ice as appearing bright as it exhibits a strong backscatter due to the roughness of the surface

(Figure 5), therefore this may be broken rough ice, possibly a result of open water pushing the ice away from shore.

Sea ice concentration is defined as the percentage of ice covered sea in proportion to the total area being observed (Lee & Han 2008). Passive microwave radars provide the majority of sea ice concentration information, although this is in poor spatial resolution. Sea ice concentration from SSM/I radars can be calculated using the different radiation that is picked up by satellites based on ice or snow covered surfaces and open ocean or both (Lubin & Massom 2006). This radiation is known as the surface emissivity, the efficiency at which a substance emits radiation at a certain temperature. Significant emissivity differences are evident between first year and multi-year ice and open ocean (Lubin & Massom 2007). Different algorithms are used to calculate the sea ice concentration based on the surface type and the radiation received by the satellite (Lubin & Massom 2006).

These images provide a greater detail of insight into sea ice processes in the Ross Sea. Comparing these images to sea ice concentration images allows an interpretation of the high resolution images using the additional information on sea ice concentration in the area from the SSM/I data. Figure 3 reveals a comparison between the two sets of images, it reveals similar characteristics in each image. In numerous areas a dark segment correlates with a lower sea ice concentration (blue colours), particularly along the edge of the Ross Ice Shelf.

The movement of ice and the ice concentration levels during the period studied in the Ross Sea suggest a polynya next to the Ross Ice Shelf (Figure 1 &2). Initially, around the 20th the area appeared white on the high resolution images, suggesting wind or unsettled conditions, there is also white surrounding the area suggesting the movement of ice, the ice also appears to drift outwards further into the ocean. During this time the sea ice concentration levels are blue and pink revealing low concentration levels, meaning there is a small amount of ice in that area. While, there is a dark/ grey area observed around the 26th and 27th, this therefore may be refreezing of ice as the polynya has depleted. The sea ice concentration images are consistent with this theory as low sea ice concentration levels are persistent throughout this period. Lubin & Massom (2007) describe a polynya as 'a recurring nonlinear opening in the sea ice cover', it may cleared of ice or consist of some ice. They can occur continuously in the same spot for weeks and sometimes months. Divergent wind and ocean regimes create latent heat polynyas, these occur closer to shore (Tamura, Ohshima & Nihashi 2008;Lubin & Massom 2006). Tamura et al. (2007) states that in winter polynyas usually freeze over quickly, therefore polynyas are covered by a thin layer of ice, occurring within 100km of the continent. Antarctic coastal polynyas exhibit a significant amount of ice production as a result of the thin ice allowing a large degree of heat out of the ocean due to poor insulation (Nihashi & Ohshima 2015). Polynyas are important mechanisms for exchanges between the atmosphere and ocean, when ice forms salt water is left in the ocean and this assists in the formation of bottom water which contributes significantly to Antarctic Bottom Water (AABW). When this water sinks it drives thermohaline circulation contributing to the global climate system (Haid & Timmermann 2012). Coastal polynyas exhibit increase biological production and biogeochemical activity, phytoplankton biomass is more significant in polynyas than in the surrounding ocean. Therefore polynyas are important sinks for atmospheric CO2 (Mathiot et al. 2012). Polynyas are important mechanisms in sea ice production and the global climate, this study suggests a polynya is able to observed in the images studied.

To the right of each image a white area is located to the bottom of a glacier tongue that heads into the ocean. This area appears blue in the SSM/I images meaning it has a lower sea ice concentration than the surrounding ice. This may suggest a polynya and due to the persistent white tone on the high resolution image it may have persisted during the whole observation period as a result of wind forcing.

SSM/Is produce low resolution images, therefore there may be some inaccuracies in the data produced, it may also been difficult to gain a deeper understanding of smaller scale properties using this type of radar and therefore less effective at studying certain subjects or areas of sea ice. Worby & Comiso (2001) describe a study carried out using SSM/I data of the sea ice edge in comparison with ship based measurements of the sea ice edge. It revealed inaccuracies in the SSM/I data where the sea ice edge was 150km off from where the ship recorded measurements. The studied also identified that different channels being more useful at identifying the sea ice edge, where the 58GHz channel was poor, the 19 GHz was the most sufficient out of five channels used in the study.

SARs are the currently most useful technique in remote sensing in polar regions, they provide detailed images of sea ice and its features (Lubin & Massom 2007). The ENVISAT images have been useful in this study in evaluating sea ice in the Ross Sea, coupled with low resolution sea ice concentration images it has deeper understanding of sea ice dynamics over a short period in this area.

Conclusion

The high resolution images enable the depiction of characteristics in the ice and water of the Ross Sea. These images have shown sea ice activity in the Ross Sea from the 20th to the 27th of May 2011 and have revealed predicted polynya activity as a result of the high detailed observed in the pictures and interpretation of the tones in the images. The comparison of the high and low resolution images reveal similarities in their compositions and structural elements of each picture reflect elements in the others. Using two sets of images from different radars is useful in gaining more information about a particular area in regards to sea ice. The Ross Sea has exhibited an increase in sea ice extent over recent decades, satellites will be useful in monitoring sea ice in this region and around Antarctica and providing information into the future.

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